Integrated PhotonPair Sources, Quantum Memories, and Lasers in Lithium Niobate

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Abstract: Recent advances of type II quasi phase matched (entangled) photon pair sources with Ti:PPLN waveguide, of quantum memories with Ti:Tm:$LiNbO_3$ waveguide, and of Ti:Tm:$LiNbO_3$ in-band pumped optical amplifiers (1700 nm < λ < 1900 nm) and lasers are reported.

OCIS codes: (130.0130) Integrated optics; (270.0270) Quantum optics;

1. Introduction

There are exciting new developments in the field of integrated quantum optics [1] exploiting lithium niobate (LN) waveguide technology: single photon pair sources with Ti:PPLN (periodically poled lithium niobate) waveguide, quantum memories with Ti:Tm:$LiNbO_3$ waveguide, and optical amplifiers and lasers with Ti:Tm:$LiNbO_3$ wave-guide for emission in the 1700 nm < λ < 1900 nm wavelength band. However, the combination of such devices in integrated circuits on a common substrate remains as a major challenge.

2. Single Photon Pair Sources

Exploiting spontaneous parametric down conversion (SPDC) in low loss Ti:PPLN waveguides, several types of single photon pair sources have been developed. Type II quasi phase matching (QPM) is preferred yielding a nar-rower photon bandwidth than type I QPM processes. Some examples are presented [2]. Among them are special, resonant sources of extremely small linewidth currently developed for photon storage in quantum memories: the wavelength of one photon matches an absorption line of a Nd- or Tm-doped crystal or waveguide quantum memory (e.g. 795 nm for Tm), while the wavelength of the other one is in a telecom band.

3. Quantum Memories

Thulium-doped Ti:LN single mode channel waveguides have recently been developed for applications as photon echo-based quantum memories. Quantum memories are key components of future quantum repeaters, which are the elementary building blocks required for long-distance quantum communication. Using Ti:Tm:LN waveguides, the storage and retrieval of photons (λ = 795 nm) from entangled photon pairs has been demonstrated, thereby tempora-rily creating entanglement between a photon and a collective atomic excitation [3]. Storage of simultaneously arri-ving, frequency multiplexed photons and recall on demand in the frequency domain has been shown as well.

4. Tm-Doped Waveguide Amplifiers and Lasers

Tm-doped LN waveguides have also been designed for the development of optical amplifiers and lasers with potential applications in optical communications, spectroscopy and sensing. By exploiting the $^3F_4 \rightarrow {}^3H_6$ transition, amplification and laser emission is within the wavelength band 1700 nm < λ < 1900 nm. As example, a simple 30 mm long Fabry-Perot type Ti:Tm:LN waveguide laser of very low threshold and 1890 nm emission wavelength will be presented. The laser has a cavity defined by dielectric end face mirrors; it is in-band pumped by a laser diode at λ = 1650 nm [4]. Longer Ti:Tm:LN waveguides can be used as optical amplifiers. Simulation results promise (wave-length dependent) gain exceeding 30 dB in 90 mm long structures.

5. References

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